



**Northern
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Department of Health
and Community Services

NHULUNBUY AND WALLABY BEACH MOSQUITO INVESTIGATION

20-23 MARCH 1995

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1.0 INTRODUCTION

Nhulunbuy is situated in Arnhem Land on the Gove Peninsula, approximately 650 km east of Darwin. It is a mining community of approximately 3,000 people associated with Nabalco Mines. The Nhulunbuy Corporation is responsible for conducting mosquito control operations in the township and has extended this service to the Wallaby Beach area at the mines request. Mosquito control includes a combination of larvicide and adult fogging operations that are conducted by a pest control contractor (Mr Dave Suter).

The major mosquito breeding sites have been identified and surveyed previously by the Medical Entomology Branch (MEB) of the Department of Health & Community Services (Booth *et al.*, 1988; Whelan and Hayes, 1992). However, following large outbreaks of the salt marsh mosquito (*Aedes vigilax*) at Wallaby Beach in 1993 it was discovered by Mr Suter that certain of the reclaimed red mud ponds ("special lease 270") were a significant and major source of *Ae. vigilax* following heavy rainfall.

The primary aim of the current survey (20-23 March 1995) by two officers from the MEB was to review the location of the major existing and potential breeding sites of *Ae. vigilax* and the common banded mosquito *Cx. annulirostris* by larval survey. Both of these species were vectors in a previous epidemic of epidemic polyarthritis and Barmah Forest virus (Whelan and Hayes, 1992). Additional traps were also set on 22 March 1995 (particularly at Wallaby Beach) to supplement the routine adult monitoring program of that week.

The mosquito control program was reviewed in consultation with the retiring Manager for Nhulunbuy Corporation (Mr Jim Fitzgerald) and Mr Dave Suter to determine any potential for improving the effectiveness of the operations and to liaise with Nabalco staff. Mr Tony O'Riley (Nhulunbuy Corporation) will be responsible for the organisation of mosquito control operations in future.

Control of mosquito breeding under the N.T. Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations (1982) is the responsibility of the land owners. Control operations for special lease 270 are currently performed by the Nhulunbuy Corporation despite the land being officially outside their jurisdiction. The costs were originally subsidised by Nabalco but are now borne by the Corporation. The lease had been returned to the traditional owners who are apparently unaware that the site is a major mosquito breeding site.

2.0 MATERIALS AND METHODS

The adult mosquito monitoring program is conducted by the Nhulunbuy Corporation in cooperation with the MEB (Darwin). The routine adult mosquito monitoring consists of setting 5 carbon dioxide baited E.V.S. type mosquito traps (Rohe and Fall, 1979) on a weekly basis. Traps are set each week by Mr Mal Stelling (Gove Hospital). Monitoring sites have been strategically placed between residents and the nearest significant mosquito breeding sites in Nhulunbuy (4 traps) and Wallaby Beach (1 trap).

2.1 Adult Mosquito Survey

The routine monitoring sites were inspected by MEB officers and an additional four traps were set at various locations on the evening of 21 March 1995 (Fig. 1). All traps were collected the following morning and dispatched to the MEB (Darwin) for mosquito identification and counting.

2.2 Larval Mosquito Survey

A total of 23 areas were designated for larval survey from 20-23 March 1995 (Figs 2 and 3) using information from previous surveys and aerial photographs. The extent and density of mosquito breeding was determined by taking a number of larval samples from each site using a standard dipper (190 ml vol.). A sample of larvae and water was transferred to specimen jars and the number of larvae per dip was recorded. Mature (fourth instar) larvae were preserved in 70 % alcohol. Immature larvae were left in specimen jars to mature. Any larvae that died prior to fourth instar were preserved in 70 % alcohol. The specific conductivity of water samples was measured in Darwin to determine the relative salinity at each sample site.

3.0 RESULTS AND SUGGESTED RECTIFICATION MEASURES

The results of adult trapping are presented in Table 1. The results of larval sampling are presented in Table 2.

3.1 Adult Monitoring

A total of 2,312 mosquitoes were trapped on 22 March 1995, consisting of 26 species. The most productive trapping site was special lease 270 at Wallaby Beach, accounting for 50.62 % of all adults trapped (Table 1). Dimbuka Rocks (12.58 %) and the depression east of the Drimmie Head causeway (11.98 %) were the next most productive sites and were also located in the general Wallaby Beach area.

The most common mosquito species trapped was *Ae. vigilax* (50.15 %), with the highest number trapped at the east end of special lease 270 (796/trap night) (Table 1). The second most common mosquito species trapped was *Culex annulirostris* (38.17 %), with the highest number trapped at the same location (358/trap night).

The other medically important species trapped was *Anopheles farauti*, a potential vector for malaria. The highest numbers were trapped at Dimbuka Rocks (20/trap night) and Buffalo Creek (11/trap night).

3.2 Larval Monitoring

Site 1. Wallaby Beach - Special lease 270 (Reclaimed red mud pond)

Special lease 270 is a large flat area east of Ybe Road. The reclaimed red mud pond has been capped with a layer of top soil (30 cm thick) although red mud was exposed in some drainage lines. A general central depression runs closer to the northern perimeter and slopes gradually to the west. The area was sparsely vegetated with *Melaleuca* and grasses. Booth *et al.* (1988) reported low levels of *Aedeomyia catasticta* in this area.

Disconnected natural drainage channels direct water to the west and at the time of survey numerous depressions were holding water throughout the lease area. Several depressions near the north east margin of the area had retained water for extended periods of time, as evidenced by *Eleocharis* reed growth around their margins.

Very high densities of second to fourth instar *Cx. annulirostris* larvae (50-100/dip) were detected in the vegetated margins and between the algal scum on the surface at the eastern end of the lease.

The creek at the base of the embankment on the eastern margin of the lease contained a broader dammed area with a mud flat and possibly salt intrusion, as evidenced by "die back" of paper barks. The creek drained north to Wallaby Beach via a culvert under Melville Bay Road. No larvae were detected along the sparsely vegetated margins of the dammed area.

Pooling toward the western edge was relatively extensive, deep and confined largely to the central access track area. Drainage from these areas was inadequate and terminated at Ybe Road, an elevated bituminised road. A rubble drain along the eastern side of Ybe Road did not extend far enough north to drain the water filled depressions to the large channel along the southern edge of the lease that discharged to Inverell Bay.

The rubble drain was adjacent to an experimental rehabilitation site that consisted of a series of elevated mounds with plantings on them. The plantings were being used to rehabilitate the dam on the south east margin of the lease with sedge grasses (Cyperaceae) and are likely to promote mosquito breeding in this area.

The margins of the depressions on the western side of the lease were either vegetated with grass or were not vegetated. Many of these depressions were holding water and had a surface layer of thick algal scum, indicating periods of prolonged pooling. Moderate densities of third to fourth instar *Cx. annulirostris* and fourth instar *An. hilli* larvae were detected. The presence of numerous other areas where water had dried so that only an area of algal scum remained indicated a potentially large area for mosquito breeding.

Rectification

Drainage of special lease 270 requires formalisation to remove the isolated pools in which very high densities of mosquitoes were observed breeding. Drains should be constructed such that no water pools for a period greater than 5 days to avoid mosquito breeding.

This would require a formalised drain in the natural depression running the length of special lease 270 and possibly a number of lateral drains to drain any peripheral deeper depressions. The main drain should be connected to the rubble drain on the east side of Ybe Rd that discharges into the main channel running along the southern boundary of the lease and ultimately into Melville Bay.

It is recommended that the MEB be consulted during any future rehabilitation works to ensure that drainage is adequate to prevent or remove mosquito breeding sites.

Site 2. Wallaby Beach interdune area

The interdune area between Wallaby Beach and Melville Bay Road was inspected for any water filled depressions. Despite recent heavy rainfall there was no evidence of water having pooled in the relatively large grassy depressions between Melville Bay Road and the elevated frontal dunes.

No rectification is necessary as the interdune depression area does not provide suitable habitats for mosquito breeding sites.

Site 3. Wallaby Beach borrow pits "Duck ponds" - North of sewage ponds

The two large borrow pits north of the sewage ponds were inspected. The margins were steep with little vegetation, except on the northern margins. Low numbers of second instar *Cx. annulirostris* larvae (2 larvae/dip) were detected in grass along the shallower northern margins. A crocodile was observed in the eastern pond.

Rectification

There are several options for the rectification of this site. The northern margin could be regularly weedicided or additionally formalised to a steep edge. In addition the pits could be stocked with fish to provide biological control of mosquito larvae. Either of these measures will ensure that numbers of disease vector mosquitoes are kept to a minimum.

Site 4. Wallaby Beach sewage ponds

Weeds were observed growing into the water around the margin of the oval shaped primary pond. Moderate numbers of second to fourth instar *Culex annulirostris* larvae (4 larvae/dip) were detected amongst the vegetation. High levels of biological control agents (aquatic bugs) were observed in the secondary ponds where the margins were relatively clear of vegetation.

Rectification

Vegetation should be weedicided and removed to promote agitation of the water surface by wind action and to improve the access of biological control agents to mosquito larvae.

Site 5. Tidal area south of Wallaby Beach sewage ponds

The mangrove margins were inspected for evidence of tidal pooling. This area has largely been rectified by the construction of a drain that delivers water from the south of special lease 270, then along the eastern margin of the sewage ponds into Melville Bay.

The impounded mangrove area and a small mudflat drain east into the main drainage channel by a smaller lateral drain with a northern and southern outlet. The impounded water was discharging through the southern lateral. Large numbers of fish were observed throughout the area and would control any mosquito larvae in open water. No larvae were detected in this area.

Storm water runoff had been impounded in two depressions (approximately 5 m x 2 m) immediately north of the tidal area. These depressions were vegetated with grass and first to fourth instar *Culex sp.* larvae were detected. This area would be a relatively minor source of mosquitoes due to the small area involved.

Rectification

At the time of inspection the northern outlet of the impounded mangrove area was not functioning and needs to be lowered to improve drainage from the mudflat area.

The two depressions north of the tidal areas would be readily eliminated by enabling stormwater to drain directly to the tidally flushed areas by means of appropriately placed runnels.

Site 6. Depression east of Drimmie Head causeway

On the western margins of the sewage pond access track a flooded paper bark swamp drains into a large depression on the eastern side of the Drimmie Head causeway. At the northern end of the paperbark swamp a low level of *Culex sp.* larvae (1 larvae/10 dips) was detected amongst *Eleocharis* reeds. Two culverts connect this depression to the tidal areas to the east. Fish were observed swimming between the depression and the tidal area to the east (described in previous section).

The southern depression was full of water, with a gradual flow of water through the culverts from the tidal area. The presence of dead paperbarks indicate the relatively recent tidal influence via culverts to the east. No larvae were detected in sampling on the east, west and south margins.

Mr Dave Suter advised that the southern depression is filled at the beginning of each wet season either by rain or tide. This year it was initially filled by rain. The area is regularly larvicided and aduulticided.

Rectification

Rectification of this depression has been previously proposed by constructing a drain westward under the causeway to Inverell Bay or filling (Whelan and Hayes, 1992).

Site 7. Gurrakpuy Beach - mangrove margin west of yacht club

The stretch of mangroves west of the sailing club was inspected for tidal pooling. The east end of Gurrakpuy Beach behind the mangrove margin was relatively steep due to an apparent land fill operation that has prevented tidal intrusion into the reclaimed area. Adult *Ae. vigilax* were observed biting MEB officers in this area.

Several depressions through the old dump had retained storm water runoff. The largest was a borrow pit (approximately 15 m x 4 m) in which no larvae were detected. The steep non vegetated margins and an abundance of aquatic biological control agents indicated that the borrow pit was not a productive breeding site. The overflow from this pit had produced an unformalised flow line south to Inverell Bay. In the grass at the edges of the flow line low numbers of *Cx. annulirostris* larvae (first and second instar) were detected. This minor source of mosquitoes may dry relatively quickly after the wet season.

Rectification

This area could be readily rectified by selective filling or rendering the borrow pit free draining by breaching the southern wall.

Site 8. Nabalco retention pond

The former security pond had recently been upgraded for use as a retention pond. Sea water will be pumped into the retention pond to neutralise caustic by-products, prior to discharge into Melville Bay. The water in the retention pond was clear blue.

Previous MEB investigations have identified this area as a major breeding site of *Ae. vigilax*. Breeding was associated with pigweed vegetation (fleshy samphire herb) on the margins (Whelan and Hayes, 1992). At the time of inspection only traces of pigweed were evident along the northern margin of the retention ponds. Mid length along the northern margin of the retention pond was an outcrop of land that is vegetated by grass.

The majority of the margins of the retention pond were steep sided except on the western margin where there is an intrusion of dry land. There were shallow pools on the dry land intrusion from recent heavy rain (63 mm in the preceding 24 hrs).

The eastern margin was not sampled because the walls were observed to be steep sided and not vegetated. The observed agitation of the water surface by wind action would also deter mosquito breeding in this area.

As part of the conversion to a retention pond a series of smaller emergency ponds were constructed on the southern margin of the retention pond. All of the ponds have steep sides that are vegetated with grass. No larvae were detected in the pond on the south west edge of the retention pond.

Rectification

Weediciding the vegetation growing into the water on the northern margin of the retention pond would remove this potential breeding site.

Shallow pools on the western margin of the retention pond, if persistent, could be effectively removed by constructing a shallow drain to the south.

Site 9. Nabalco red mud pond 3 (dry mud)

A previously productive breeding site was the eastern corner of the dry red mud pond (previously identified as swampland NE of red mud pond; Whelan and Hayes, 1992). This pond had been extensively utilised as a storage area for dry mud.

The absence of surface pooling has eliminated it as a mosquito breeding site.

Site 10. Swamp between red mud pond 3 and red mud pond 5

Another previously productive breeding site for *Ae. vigilax* was the swampy ground north of Dimbuka Rocks between the dry red mud pond 3 and red mud pond 5 (Whelan and Hayes, 1992).

At the time of inspection this area had been rectified due to the extension of the mud pond into this area. There was no vegetation at the margins of this pond.

Site 11. Salt flat south west of Dimbuka Rocks

High densities of *Cx. annulirostris* (20 larvae/dip) were collected amongst reeds at the northern margin. The presence of this species indicated an input of stormwater run off or seepage into this area, as previously identified by Booth *et al.* (1988). The absence of disconnected pools in the tidal area may have been due to the input of storm water runoff. The depth and softness of the mud in this area and the potential exposure to crocodiles restricted sampling to the eastern margin.

The edges of the tidal flat area further south along the western side of red mud pond 5 were mostly not vegetated and no larvae were detected.

Rectification

This area will require re examination after the wet season to determine the extent of input from seepage and level of mosquito breeding. Shallow surface drainage may be needed to direct seepage and storm water run off from the areas surrounding Dimbuka Rocks into the lower tidally influenced areas. Rectification of this area is warranted due to the high number of adult *An. farauti* that were trapped near this site. Selective filling of the salt flat from the eastern edge should also be investigated.

Site 12. Nabalco red mud pond 5

At the time of inspection the north east part of this pond did not contain suitable or available breeding grounds. There were large mounds of red mud with pooling but no vegetation.

Site 13. Nabalco quarry east of red mud pond 5

The depressions of the quarry runoff had collected water with a suspended colloidal clay content. Prolonged pooling in these areas may generate vegetative growth. No larvae were detected in these pools.

Site 14. Crocodile Creek

An interdune depression immediately south of Crocodile Creek is under tidal influence. The depression was heavily vegetated with mangroves and does not drain readily. The margins on the eastern and southern sides of the depression were grassed. This area was previously identified as an *Ae. vigilax* breeding site (Whelan and Hayes, 1992) and is larvicided and fogged on a regular basis.

The presence of moderate levels of *Cx. annulirostris*, *Cx. sitiens* and *Uranotaenia lateralis* larvae (30/dip) amongst the grass on the eastern margin of the depression indicated that the depression had recently been subjected to fresh water influence from recent heavy rain.

The interdune depression is situated east of other paperbark swampy depressions that extend west toward Wallaby Beach. These large swampy depressions had very low levels of *Cx. annulirostris* larvae, probably due to the efficacy of the biological control agents.

Adult *Ae. vigilax* and *Ae. funereus* were observed biting MEB officers at this site. This area is larvicided and fogged on a regular basis.

Rectification

There are two options for rectification of this site. The depression could be rendered a relatively unproductive mosquito breeding site (i.e. a fresh water paperbark swamp) by the removal of the tidal influence of Crocodile Creek. This would necessitate constructing a barrier between the interdune depressions and across the mangrove flow line and removing the mangroves.

Alternatively the drainage channel for the depression could be deepened to a depth that would enable more frequent tidal flushing of the site to remove *Ae. vigilax* breeding sites. More frequent tidal flushing of the depression may also remove fresh water mosquito breeding site around the southern and eastern margins of the depression.

Site 15. Western mudflats and associated creek line

This site is an area of East Woody Creek consisting of a large mudflat fringed by mangroves. At the tidal margin several shallow depressions retain water beneath the mangrove canopy and have been previously identified as productive mosquito breeding sites for *Ae. vigilax* (Whelan and Hayes, 1992). This area is regularly larvicided and fogged.

At the time of inspection *Ae. funereus* adults were observed biting MEB officers and low levels of *Cx. sitiens* larvae (Table 2) were detected in isolated areas amongst the grass. These pools were being maintained by storm water runoff.

The narrow creek line approximately 30 m south of the tidal margin had a well defined margin and was flowing freely. No larvae were detected in the creek although it has previously been identified as a productive breeding site (Booth *et al.*, 1988; Whelan and Hayes, 1992) and is checked regularly by the pest control operator.

Rectification

The shallow depressions at the mangrove margin should be filled. The remainder of this area should continue to be regularly inspected and larvicided when necessary.

Site 16. Nhulunbuy sewage ponds

The water surface at the north west corner of the primary pond was congested with a combination of artificial floating debris and algal scum. The long grass vegetating the north west margin indicated that debris may have been present for some time.

Amongst the vegetation and debris on the NW corner were high numbers of third and fourth instar *Cx. sitiens* (90/dip) and *Cx. annulirostris* (10/dip). Lower levels of these species were

sampled at the southern corner, indicating that this pond was a productive source of mosquitoes. There were relatively low numbers of larvae in the sparse vegetation along the other margins of the primary pond.

Rectification

The debris and algal scum should be cleaned out and the vegetation weedicided and removed to prevent further mosquito breeding.

The margins of the secondary and tertiary pond were not vegetated and there was no surface debris. Agitation of the water surface by wind action and biological control agents were effectively controlling any mosquito breeding.

Site 17. Nhulunbuy overflow pond of sewage pond

The majority of the overflow pond was dry and heavily grassed, indicating it had not been used for some time. Surface water was confined to the western end. No mosquito larvae were detected but there was an extremely high level of biological control agents (50-100/dip adult and immature "water boatman" aquatic bugs, Hemiptera:Notonectidae).

Site 18. Mt Saunders sewage pond

This sewage pond consists of a single pond. The margins were vegetated at water level but only an isolated patch of *Cx. annulirostris* fourth instar larvae (2/dip) was detected.

The overflow pipe is located on the western margin of the pond. The small concrete lined storm water drain that runs parallel to the western margin of the sewage pond was largely choked with vegetation. Water disappeared underground from both the overflow pipe and storm water drain toward the north boundary fence.

The underground overflow pipe surfaces prior to the northern boundary fence of the sewage pond enclosure. Effluent overflow was discharging into an unformalised area that subsequently drained to the creek line approximately 30 m north. The discharge of effluent prior to the creek line had created an area of swamp with a rain forest canopy. The creek itself was flowing freely, with a well defined sandy bottom and minimal vegetation on the margins prior to entering the artificial swamp. No mosquito larvae were detected in the swamp or creek.

Rectification

The swampy area could be rectified by extending the overflow pipe from the sewage pond into the creek line and thereby reduce the area available as a mosquito breeding site. Similarly the storm water drain should be cleared and extended to the creek line to prevent unnecessary pooling and the subsequent formation of mosquito breeding sites after the wet season.

Site 19. Nhulunbuy "south"

This site is the end point of a drain that formally serviced a sewage treatment plant. The margins of the drainage line were extremely overgrown with vegetation although storm water was flowing freely to the end point. The drain discharged into a unformalised channel and flooded a large area that was densely vegetated with a thicket of an unidentified woody shrub.

No larvae were detected in the drain or the overflow area.

Site 20. Nhulunbuy Lagoon

Rain had filled the lagoon so that its margins extended onto the western track used for fogging operations. The extensive *Typha* reed areas previously identified as productive breeding sites were inundated and are being progressively reduced by a weediciding reduction program conducted by the Nhulunbuy Corporation.

Larvae were not detected along the lagoon margins at the north west reed area of the northern lagoon, the "rear Jasper" adult mosquito monitoring site or at the mouth of the lagoon (from which large volumes of water were discharging into the sea).

Site 21. Nhulunbuy golf course

Storm water drainage in this area discharges to an open grass lined drain (OUD). The grass areas of the golf course are irrigated by effluent which adds to the organic levels in these drains and ultimately Nhulunbuy Lagoon. The OUD runs through a natural depression that is low on the contour profile. At the time of inspection drainage was being impeded because the eastern end of the OUD was lower than the wet season stabilised level of Nhulunbuy Lagoon. An algal bloom was present on the water surface, indicating nutrient rich water was directly entering Nhulunbuy Lagoon.

At the western end of the OUD the drain was very boggy from recent mowing. There were a few isolated pools beyond the OUD margin. No larvae were detected at the golf course. However the OUD and any other areas had recently been larviced.

Rectification

Rectification of this area would require filling of the depression to a level above the wet season stabilised level of Nhulunbuy Lagoon. Rectification of the ecological effects of effluent reuse requires the discharge of run off water from the golf course to go through a treatment lagoon or constructed wet land filter before discharge into Nhulunbuy Lagoon. Low flows in the dry season should not be allowed to discharge into Nhulunbuy Lagoon.

Site 22. Nhulunbuy - roadside drainage

Drainage into Nhulunbuy Lagoon from Jasper Road was inspected where it is directed into Pandanus Close due to a mosquito complaint received by the environmental health officer (Mr Phil Donohoe). Water was flowing despite the drain being heavily vegetated. It was noted that roadside drainage was not directly connected to the lagoon. Stormwater from this

and some of the other roadside drains discharges on to the fogging track before it reaches the lowest drainage points to the lagoon.

A brief inspection of different storm water sites showed that water was flowing from Beagle Circuit and Jasper Rd into Nhulunbuy Lagoon.

No larvae were detected in the freely flowing drains.

Rectification

Roadside drainage on the east side of Beagle Circuit would benefit from weedciding and desilting to prevent the formation of isolated pools and subsequent creation of mosquito breeding sites after the wet season.

Site 23. Buffalo Creek

The creek margins were briefly inspected on 23 March 1995 after a short rain episode. The creek line margin was generally indistinguishable from surface flooding that extended to the fogging track due to the large amount of rain water run off. No larvae were detected in the general area.

3.3 Summary of Larval Monitoring

The most common species sampled was *Cx. annulirostris*. This species was collected throughout the Nhulunbuy and Wallaby Beach area in water that varied from being very fresh (0.14 mS/cm) at Mt Saunders sewage pond to brackish pools on the western mudflat mangrove margins (18.14 and 28.0 mS/cm).

The highest densities of *Cx. annulirostris* (50-100/dip) were collected in the north east depressions of special lease 270 at Wallaby Beach and the mangrove margin at Crocodile Creek (10-30/dip). The largest areas of breeding were on the reclaimed red mud pond (special lease 270).

Aedes vigilax larvae were collected at relatively low densities in isolated areas at the reclaimed red mud pond (5/ dip) and one larva collected in a small pool behind Wallaby Beach dunes towards Crocodile Creek. The water at both sites was relatively fresh (1.82 mS/cm and 0.01 mS/cm respectively).

Culex sitiens (the salt water Culicine) was sampled at high densities in combination with *Cx. annulirostris* at the primary pond of the Nhulunbuy sewage ponds (90/dip), moderate densities at the western mudflats and at a low density at the reclaimed red mud pond (1/dip).

Anopheles hilli larvae were also recovered in low densities (1/dip) at the western end of the reclaimed red mud pond. The area of water indicated that it is probably a productive breeding site.

Mosquito larvae were not detected at the Nabalco Mine retention pond or current red mud pond sites, the depression on the eastern side of the Drimmie Head causeway, Nhulunbuy Lagoon, Buffalo Creek or the Nhulunbuy South site.

3.4 Discussions with Nabalco Management

3.4.1 Red mud pond onsite supervisor

A brief discussion was held on 23 March 1995 with the red mud pond onsite supervisor (Mr Dennis Kellett) to summarise the results of the larval survey in the red mud pond area. He informed MEB officers that the discharge of water from the retention pond was waiting on permission from the Power and Water Authority. The high water level of the retention pond was to be maintained by pumping sea water in when necessary.

Mr Kellett was aware of plans to construct a drain from the Drimmie Head causeway depression west to Inverell Bay. However the area was outside his jurisdiction and he was unaware of the current timetable for drain construction. Special lease 270 was now in the process of rehabilitation by the Nabalco Environmental section. He arranged a meeting with the officer responsible for the rehabilitation of the reclaimed red mud pond area (Mr Jim Bawden).

3.4.2 Environmental management

A brief meeting with Mr David Blaxland (representing Mr J. Bawden) was held on 23 March 1995 to discuss the current mosquito breeding problems areas, their possible solutions and the status of the Drimmie Head causeway depression drain.

The extent of mosquito breeding in depressions in special lease 270 was outlined. The MEB suggestion to target depressions in which mosquito breeding was occurring first and connecting natural drainage lines was not considered an option because the area would be contaminated if not done in conjunction with the rehabilitation project. Mr Blaxland advised that the lease area was in the process of a five year program to rehabilitate at 10 ha./year. Rectification of mosquito breeding sites had not been considered an issue in this program.

The inadequacy of the rubble drain at the western end of the lease was also reported. Mr Blaxland advised that the rubble drain at the south west corner of the site could be extended after the wet season when the substrate had hardened.

MEB outlined that weediciding of the ponds north of the Wallaby Beach sewage pond would be beneficial in limiting the extent of mosquito breeding. Mr Blaxland advised this conflicted with the current strategy of retarding the velocity of run off water by using aquatic vegetation, as evidenced by plantings of the dam margins on the south east corner of special lease 270 with sedge grass (Cyperaceae).

Mr Blaxland was unaware of any plans to construct a drain from the depression on the east side of the Drimmie Head causeway westward to Inverell Bay.

3.5 Fogging track inspection

An intensive fogging program to control adult mosquitoes is conducted by the Nhulunbuy Corporation throughout Nhulunbuy and Wallaby Beach on a seasonal basis. Malathion (ULV) is sprayed from a 4 WD mounted "Leco" fogger. The flow rate has been set to 93 ml/min. A trap catch of 100 mosquitoes per night has been the threshold level for initiating fogging operations, which vary in frequency from 3-6 times a week. Fogging operations are

conducted at a frequency of six times a week during the *Ae. vigilax* outbreaks (more than 50 in a trap per night). Fogging operations were reduced from a frequency of six times per week to three times per week a fortnight before the MEB survey due to the general decline in mosquito numbers.

On the evening of 22 March 1995 the fogging tracks were inspected with Mr Dave Suter during a fogging operation. Sunset was at 1850 hrs. The duration of the fogging operation was from 1745 hrs until 1940 hrs. Several areas of the fogging track on the west margin of the lagoon were very boggy. These sections of the fogging track require should be upgraded with rubble before the next wet season.

3.6 Revision of fogging regime

Booth *et al.* (1988) suggested the following fogging regimes for *Ae. vigilax*, *Cx. annulirostris* and *Anopheles* species based on the number of female mosquitoes trapped on any given trap night. When *Ae. vigilax* numbers were greater than 50/trap night a fogging frequency of once a week was recommended. When more than 100/trap night were caught a fogging frequency of twice a week was recommended. Fogging once a week when the numbers of *Cx. annulirostris* or *Anopheles* species were greater than 100/trap night. The fogging frequency was recommended to increase to twice a week on occasions when over 200/trap night were trapped.

To date each fogging operation has included Nhulunbuy Lagoon, Buffalo Creek, western mudflats of East Woody Creek, Wallaby Beach and Nhulunbuy "south". The time taken to fog these large areas has necessitated fogging some areas during periods when mosquito activity was probably low. Fogging operations would be more efficient if the operation was divided over two nights to ensure that fogging in each area is conducted during periods when mosquito activity is highest. It is recommended that the fogging threshold be revised from Booth *et al.* (1988) to the frequencies presented in Figures 4 and 5.

The revised thresholds should be applied to the "Rear Jasper", "Contractors Village" and "Buffalo Creek" sites as they are the closest to residential areas. It should be noted that the fogging frequency for *Ae. vigilax* numbers greater than 100/night has been increased to three times a week to cater for the period when the risk of disease transmission (epidemic polyarthritis and Barmah Forest virus) is high (see Whelan and Hayes, 1992).

4.0 DISCUSSION

Adult mosquito monitoring indicated that the eastern end of special lease 270 at Wallaby Beach was the most productive site of "the salt marsh mosquito" *Ae. vigilax* and "the common banded mosquito" *Cx. annulirostris*. These species are the primary vectors of epidemic polyarthritis and Barmah Forest virus disease in coastal N.T. Previous outbreaks of these diseases in Nhulunbuy (Merianos *et al.*, 1992; Whelan and Hayes, 1992) coincided with large numbers of these species. *Culex annulirostris* is also the vector for Australian encephalitis.

Aedes vigilax lay eggs in the impounded upper tidal areas that are filled after the high spring tides or after rain. Eggs are laid above the receding water line, on moist or drying mud and the bases of salt marsh plants. The eggs can resist desiccation for long periods and hatch when flooded by the next rain or high tides. Due to the ephemeral nature of the breeding sites larvae from each hatching event (tide or rain) develop quickly and emerge in synchrony. The larval stages usually last four days before pupation (an additional 2 days) and then the adults emerge. The females usually take another 2 days to mate and lay the first batch of eggs before they disperse in search of blood meals.

The high numbers of *Ae. vigilax* adults trapped at the eastern end of special lease 270 indicated that there had been a relatively recent hatch of this species. The presence of *Ae. vigilax* larvae in the depressions in special lease 270 may indicate that these pools may indicate the habitat was initially saline from the red mud process and any subsequent salinity may be the result of the progressive exposure of the red mud from top soil erosion. Flooding of the depressions in the wet season removes suitable habitat and prevents further egg laying.

The timing of larval survey and control operations for *Ae. vigilax* is critical. Whelan and Hayes (1992) advised that larval surveys should be conducted 2-3 days after spring tide heights over 3.4 m ACD or significant rainfall (25 mm in a 24 hr period). For very large tides it will be necessary to do a follow up survey after the highest tide over 3.4 m ACD as there may be several days where tides exceed the critical tide height and cause subsequent *Ae. vigilax* egg hatches. A delay beyond four days will necessitate the relatively inefficient control of adults by fogging.

Waiting for increases in numbers of adult trapped to determine when larval surveys and control operations are to be conducted will be ineffective for the control of *Ae. vigilax*. Egg hatching will generally occur within one day following tides over 3.3 or 3.4 m ACD, or rainfall in excess of 25 mm over a 24 hr period. Effective control depends on monitoring larval sites 2-3 days after environmental events that will trigger egg hatch.

Bacillus thuringiensis variety *israelensis* (B.t.i.) is the larvicide of choice. It is very effective and specific in killing mosquito larvae that are early fourth instar or younger. Other biological control agents such as aquatic beetles, fish, dragonfly and damselfly larvae are not harmed by B.t.i. Treatment with "Abate" temephos 1 % granules should be reserved for occasions when larvae have reached later fourth instar and will no longer be killed by B.t.i.

Culex annulirostris breeds in less ephemeral fresh water habitats, e.g. ground water depressions associated with vegetation. The larval instars are comparatively prolonged (approximately seven days). In established mosquito breeding sites it is often possible to take a larval sample in which all aquatic stages are present. Prior to the MEB visit there were significant and prolonged episodes of rain. The effect of sustained rainfall (63 mm were recorded at Gove airport in the 24 hours prior to 0900 hours on 20 March) was the flushing out of many possible existing mosquito breeding sites. The presence of high densities of *Cx. annulirostris* in depressions in special lease 270 indicated that recent heavy rainfall had probably hatched out all of the *Ae. vigilax* and once flooded, become suitable for *Cx. annulirostris*.

The absence of mosquito larvae at many sites (e.g. Nhulunbuy Lagoon, Buffalo Creek, depression east of the Drimmie Head causeway) was a combination of recent successful larvicide operations conducted on the 15 March 1995 and the hatching out of any remaining

Ae. vigilax in the breeding sites after recent heavy rainfall. As the water levels recede in these locations after the wet season the formation of isolated pools will provide shelter for the larvae from biological control agents. Subsequently *Cx. annulirostris* can be expected to increase for a period before the isolated pools dry out as the dry season progresses.

The success of adult mosquito control operations are dependent on the suitability of several factors including wind speed, wind direction, relative humidity and vehicle speed. Fogging operations are most effective during the period from dusk and the following hour. This corresponds to the period when mosquito flight activity is at its highest. During periods of plague numbers of *Ae. vigilax* it would be acceptable to commence earlier due to the tendency of this species to be active before dusk.

The time required to fog all areas in Nhulunbuy and Wallaby Beach on any given night has necessitated fogging at times when mosquito flight activity was probably low. The fog is most effective in killing flying insects. To more effectively target mosquitoes during the time of peak flight activity, the fogging program would be better if it was divided over two nights. Hence the fogging frequencies in Figs 4 and 5 could be readily applied.

Rectification of most of the larval breeding sites located in this survey would be relatively cheap and simple. However rectification measures to prevent the direct discharge of nutrient rich water from the Nhulunbuy golf course into Nhulunbuy Lagoon should be investigated. The input of nutrient rich water will promote the establishment of semi-aquatic vegetation and aggravate mosquito breeding throughout the lagoon.

The rectification of drainage patterns in special lease 270 may present difficulties due to the thinness of topsoil. Because the area is under gradual rehabilitation it is probably more cost effective to use larvicides until rehabilitation is complete. It would be pertinent to take into account the problem drainage at the present site when conducting future rehabilitation of other red mud areas. The productivity of this site for the two major disease vectors indicated that rectification of this area should be a high priority before the next wet season.

The discovery of special lease 270 as a significant mosquito breeding site means that diligent larval monitoring and control will effectively reduce the levels of disease carrying mosquitoes near areas where Nhulunbuy residents socialise (sailing club) or conduct outdoor leisure pursuits (fishing, boating). Timely control operations may also reduce the impact of *Ae. vigilax* on Nhulunbuy residential areas as this species can disperse over relatively long distances from their breeding sites. However it must be recognised that other significant *Ae. vigilax* breeding sites also contribute to the problem (Buffalo Creek, western mudflats, Rainbow Cliff Creek and mangrove areas to the south of Nhulunbuy).

5.0 CONCLUSIONS

The old red mud ponds at special lease 270 (Wallaby Beach) are a productive source of *Ae. vigilax* and *Cx. annulirostris* following significant rain (over 25 mm in a 24 hr period). Both species pose a potential health risk to residents and Nabalco staff as they are the vectors of epidemic polyarthrititis in the coastal N.T.

The breeding sites in special lease 270 are the result of poor storm water surface drainage. Rectification of breeding sites in this area should be incorporated into the ongoing rehabilitation plan.

The expansion of red mud pond 3, the construction of emergency retention ponds and current water management strategy has apparently significantly reduced the numbers of mosquito breeding sites within the red mud pond area. The rectification of the waterhole near the Drimmie Head causeway would further reduce the number of productive mosquito breeding sites. The salt flat area south of Dimbuka Rocks will probably continue to be a significant source of mosquito breeding. The potential for selective filling of the breeding sites located in this survey should be investigated.

The primary sewage ponds at Nhulunbuy township were a significant breeding site for *Cx. annulirostris* and *Cx. sitiens*. The sewage pond outfall from Mt Saunders sewage pond is also likely to become a significant breeding site of *Cx. annulirostris* after the wet season when isolated pools are formed between the broken outlet pipe and the creek line. The Mt Saunders sewage pond needs the overflow pipe to be extended into the creek line, to prevent unnecessary pooling of nutrient rich water.

The primary pond of the Wallaby Beach sewage ponds were a moderate source of mosquito breeding due to the vegetation growing around the perimeter. The rectification of the Nhulunbuy and Wallaby Beach sewage ponds requires clearing of surface debris and weediciding, respectively.

Pooling at the edge of the western mudflats has provided a small mosquito breeding site that could be easily rectified by filling. A previous survey in November 1993 (Appendix 1) showed the creek that discharges into this area was an extremely productive breeding site of *Ae. vigilax*. Engineering of the creek however is not feasible as it lies outside the town lease. The creek will therefore continue to need to be surveyed for larvae after high tides and significant rainfall and larvicided when required.

Nhulunbuy Lagoon, Crocodile Creek and Buffalo Creek were not significant sources of mosquito breeding at the time of survey due to recent heavy rain that had flushed out any potential mosquito breeding sites. Monitoring of these areas will need to continued especially at the beginning of the wet season and after high tides before the rainy season.

The timing and frequency of fogging operations may benefit from revision. Any fogging before dusk during periods when *Ae. vigilax* is not evident is not warranted. Fogging operations would be more efficient if each operation was divided over two nights. Hence each area would be fogged 3 times a week but the fogging would be more productive as it would be done during the period when mosquito activity is greatest. Fogging along the top wall of red mud pond 3 is probably not effective in windy conditions as this is an exposed location above the breeding sites and should only be fogged when areas can not be larvicided, and environmental conditions of wind speed and direction are optimum.

The fogging track in several areas on the western side of Nhulunbuy Lagoon has become extremely boggy and requires upgrading before the next the wet season.

6.0 RECOMMENDATIONS

1. The rehabilitation of special lease 270 to prevent mosquito breeding during the wet season should be given a high priority. Over the last few years this site has been a major breeding

site of disease vector mosquitoes. The current revegetation strategy may be in conflict with the need to prevent the creation of mosquito breeding sites. The recurrent costs of larval survey and control operations (estimated by Mr Jim Fitzgerald to be as high as \$ 30,000 per annum) could be minimised by rectifying drainage from this site. Consultation with the Medical Entomology Branch in the rehabilitation of this area is recommended to minimise the potential for creating a permanent, extremely productive breeding site for disease carrying mosquitoes.

2. Careful monitoring for larvae at the special lease 270 site, no later than three days after significant rainfall (25 mm in a 24 hour period), is required to prevent instances of mass emergence of *Ae. vigilax* at the beginning of the wet season. Treatment with B.t.i. should be used whenever necessary.
3. A commitment should be obtained from Nabalco for the drainage or filling of the depression east of Drimmie Head causeway. This site is a productive breeding site of disease carrying mosquitoes close to the residents of Wallaby Beach.
4. Rectification of the interdune depression that is subject to tidal influence south of Crocodile Creek is recommended. This site could either be removed from tidal influence by the construction of a sandbar at its eastern end. Alternatively the channel connecting the depression to the creek could be deepened to expose the eastern end to a more frequent tidal regime.
5. Small depressions on the fringe of the western mud flats should be filled. These are shallow depressions which hold water after the high spring tides and subsequently become productive sites of *Ae. vigilax* relatively close to the residents of Nhulunbuy.
6. Mosquito breeding located in the tidal areas of the creek line that connects the Mt Saunders sewage pond to the western mud flats (as identified in previous reports) was not evident during the current survey. The creek line should continue to be surveyed for larvae and larvicided when required.
7. Mosquito breeding at the Nhulunbuy primary sewage pond should be remedied by the removal of surface debris.
8. The Mt Saunders sewage pond overflow pipe should be continued to the creek line to prevent the pooling of nutrient rich water and the formation of mosquito breeding sites between the pond and the creek.
9. Alternatives to the direct discharge of effluent rich water from the Nhulunbuy golf course into the Nhulunbuy Lagoon need to be investigated. The run off water from the golf course needs to be directed either through a treatment lagoon or a wet land filter.
10. The fogging track should be upgraded with rubble or sand in boggy areas on the west side of Nhulunbuy Lagoon to facilitate effective fogging operations.
11. The fogging routes should be divided over two nights. The large area that is required to be covered in one night is such that the fog for much of the operation may be less effective, with the possible exception of outbreaks of plague numbers of *Ae. vigilax*.

Hence fogging could be restricted to areas near Nhulunbuy (Lagoon and Buffalo Creek) on one night and the remaining areas covered on the consecutive night.

7.0 ACKNOWLEDGMENTS

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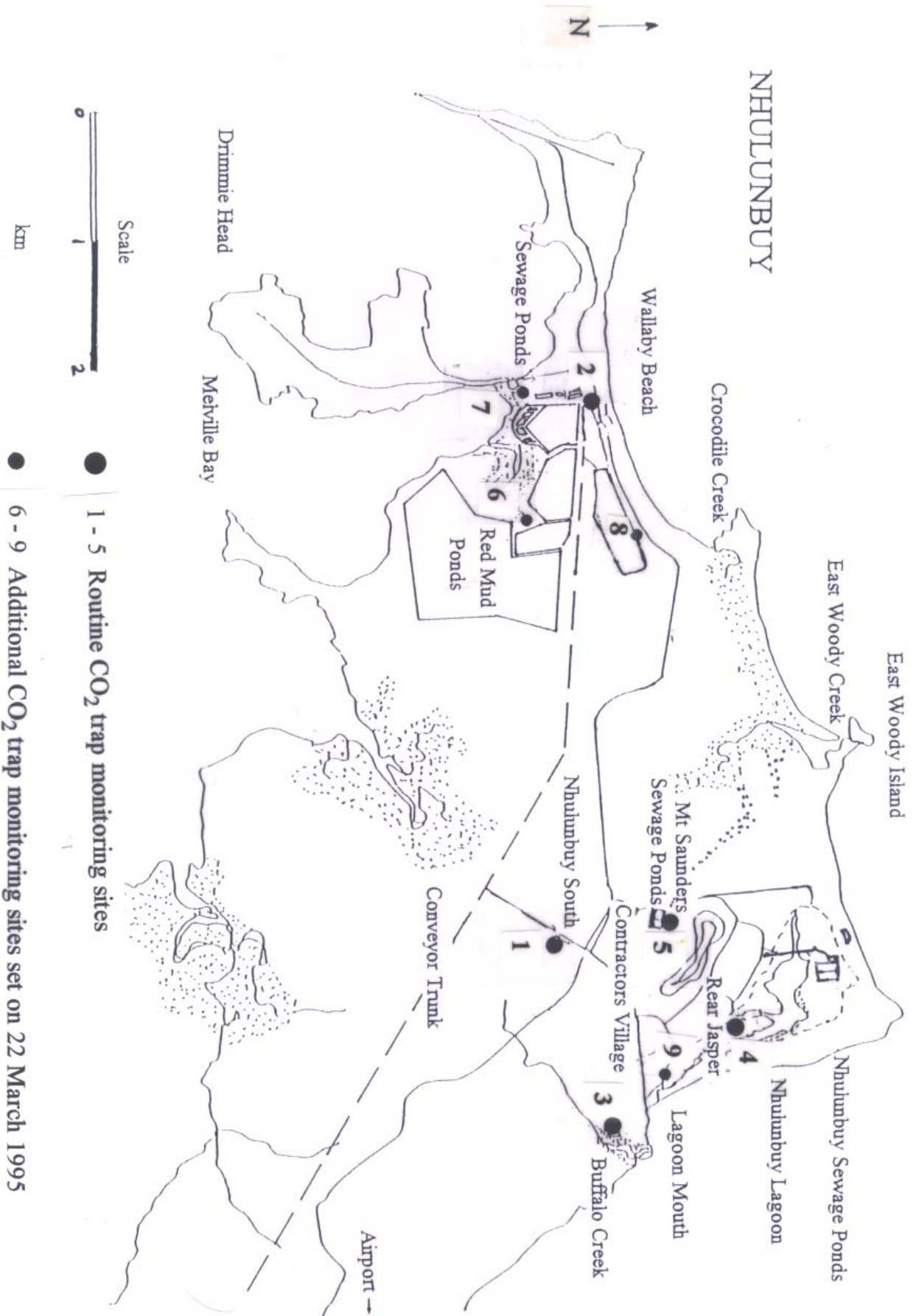


Figure 1. Nhulunbuy mosquito monitoring sites - 22 March 1995.

Larval Survey Sites

1. Special Lease 270
2. Wallaby Beach interdune area
3. "Duck Ponds"
4. Wallaby Beach sewage ponds
5. Tidal area
6. Depression east of Drimmie Head causeway
7. Gurrakpuy Beach
8. Nabalco Retention Pond
9. Nabalco Red Mud Pond 3
10. Swamp between Pond 3 and Pond 5
11. Salt Flat south of Dimbuka Rocks
12. Nabalco Red Mud Pond 5
13. Nabalco Quarry
14. Crocodile Creek
15. Western mud flats



Figure 2. Larval monitoring sites in the Wallaby Beach and Red Mud Pond area. Nhulunbuy 20 -23 March 1995.

- Larval monitoring sites
15. Western mudflats
 16. Nhulunbuy sewage ponds
 17. Overflow pond of sewage pond
 18. Mt Saunders sewage pond
 19. Nhulunbuy "south"
 20. Nhulunbuy Lagoon
 21. Nhulunbuy golf course
 22. Roadside drainage
 23. Buffalo Creek

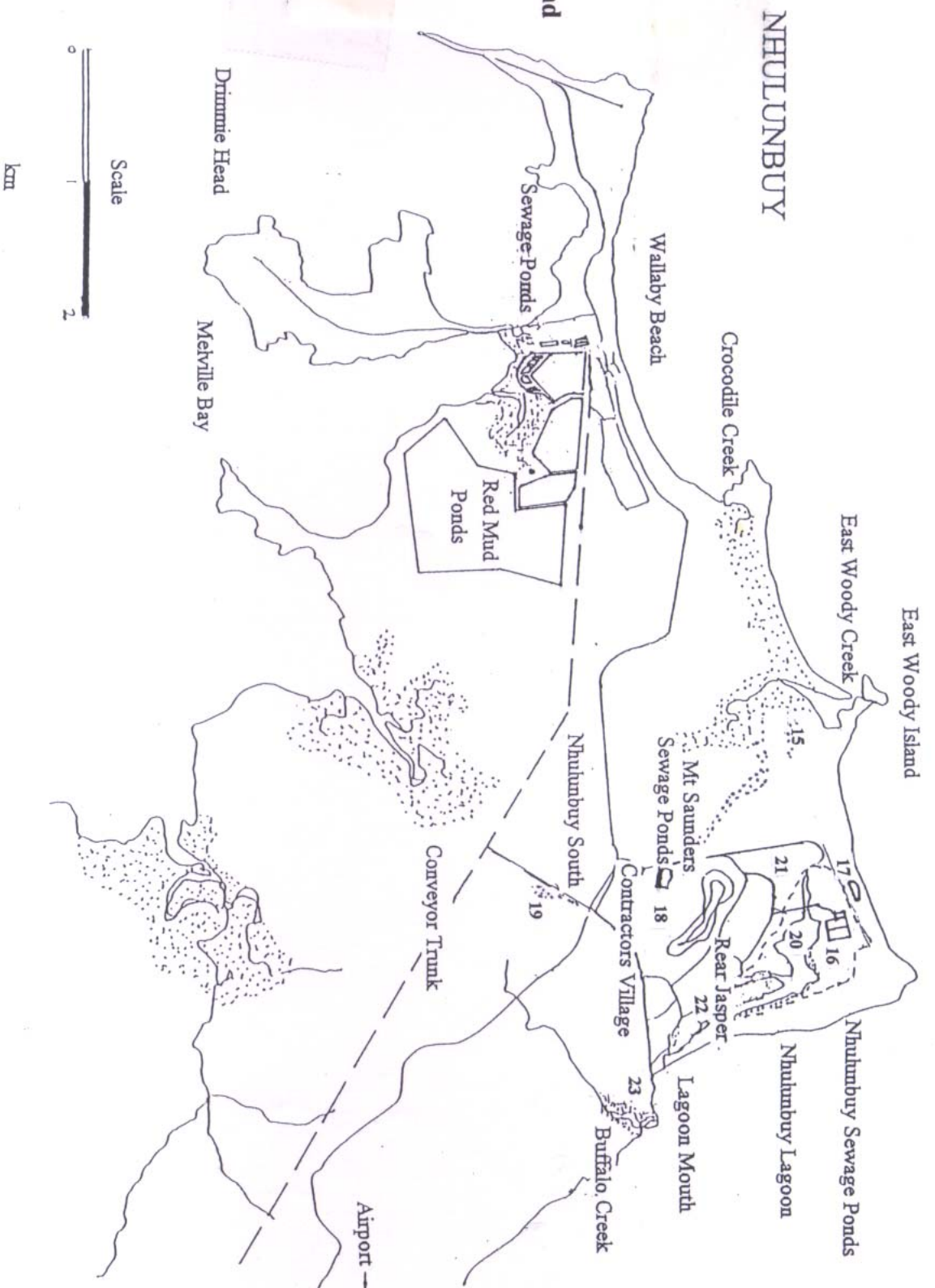


Figure 3. Larval monitoring sites in the Nhulunbuy area.
Nhulunbuy 22 - 23 March 1995.

**Figure 4. Fogging thresholds for *Culex annulirostris* at Nhulunbuy for collections at sites near residential areas.
Fogging should continue until numbers fall below the threshold levels for two consecutive weeks.**

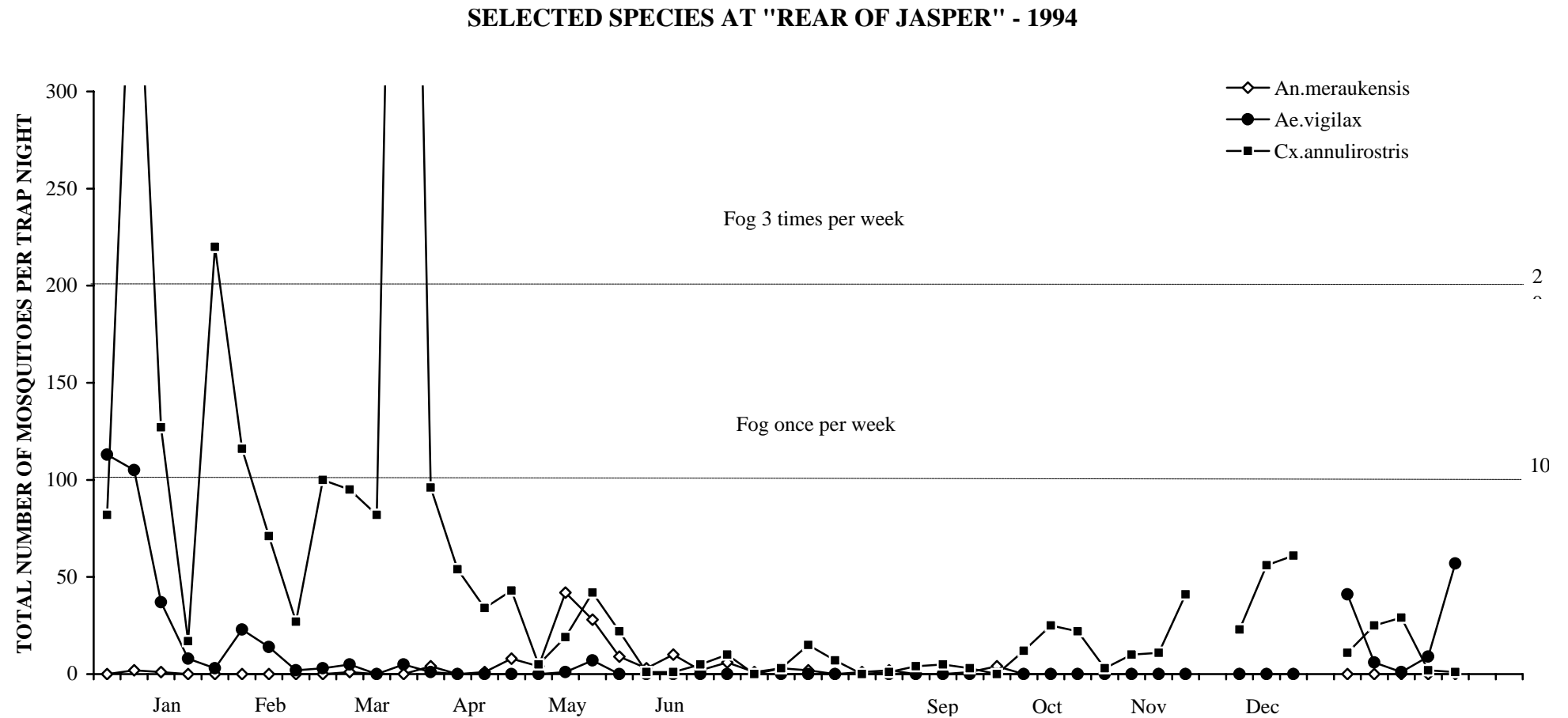
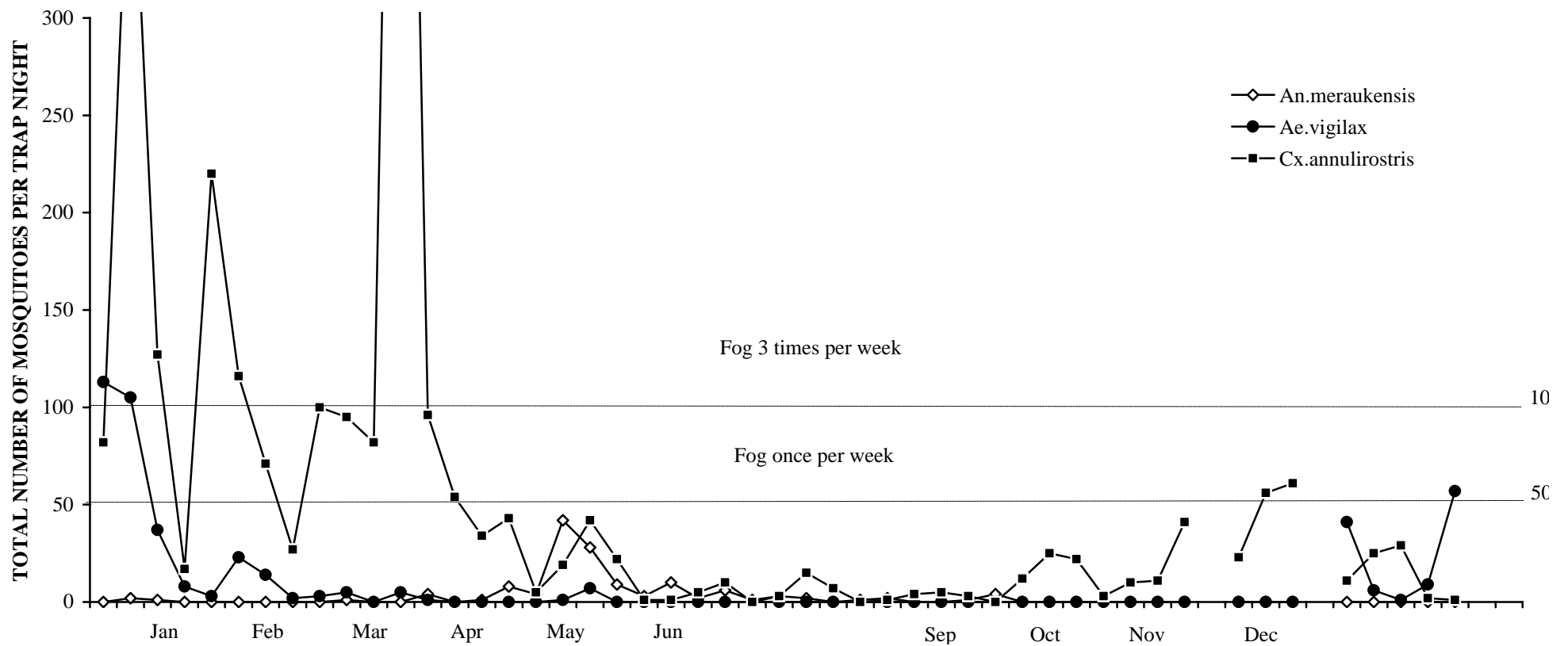


Figure 5. Fogging thresholds for *Aedes vigilax* at Nhulunbuy for collections at sites near residential areas.
Fogging should continue until numbers fall below the threshold levels for two consecutive weeks.

SELECTED SPECIES AT "REAR OF JASPER" - 1994



**TABLE 1. ADULT FEMALE MOSQUITOES CAUGHT USING CO2 BAITED EVS MOSQUITO TRAPS.
NHULUNBUY, 22 MARCH 1995.**

SITE NO.	TRAP LOCATION	MOSQUITO SPECIES																								TOTALS	% OF TOTALS		
		An. amictus	An annulipes	An. farauti	An. hilli	An. meraukensis	An. novaguinensis	Ae. alternans	Ae. daliensis	Ae. elchoensis	Ae. funereus	Ae. kochi	Ae. lineatopennis	Ae. notoscriptus	Ae. pecuniosus	Ae. phaeasiatus	Ae. reesi	Ae. vigilax	Ae. (Mac.) sp. 76	Cx. annulirostris	Cx. sitiens	Cx. (Loph.) hilli	Cx. (Loph.) sp. 167	Ad. cataicta	Cq. xanthogaster			Ma. uniformis	Ur. lateralis
1	"Nhulunbuy South"			6		2						1		15			21	21		37							2	105	4.52
2	"Wallaby Beach"			1	5								1					37		49	1							94	4.05
3	"Buffalo Creek"	1	2	11		9	3			1	4			5	1			15		24								76	3.27
4	"Rear Jasper"											1		1				4		149			1		1			157	6.76
5	"Contractors' Village"			1		1						1		3			1	1		39								47	2.02
6	Dimbuka Rocks			20								6		1		2		151	1	85	25				1			292	12.58
7	Depression east of Drimmie Head causeway			3				3	2									128	1	86	48			7				278	11.98
8	Special lease 270 (north east)				12			1										796		358	8							1175	50.62
9	Mouth of Nhulunbuy Lagoon			1							1			21				11		59	1	1				2		97	4.18
	TOTALS	1	2	43	17	12	3	4	2	1	5	9	1	46	1	2	22	1164	2	886	83	1	1	7	2	2	2	2321	100.00
	% OF TOTALS	0.04	0.09	1.85	0.73	0.52	0.13	0.17	0.09	0.04	0.22	0.39	0.04	1.98	0.04	0.09	0.95	50.15	0.09	38.17	3.58	0.04	0.04	0.30	0.09	0.09	0.09	100.00	

TABLE 2. MOSQUITO LARVAL SURVEYS. NHULUNBUY 20 - 23 MARCH 1995.

LARVAL SITE NO. #	DATE	LOCATION	SPECIES	INSTARS	NO. OF LARVAE PER DIP	SPECIFIC CONDUCTIVITY* (mS/cm)
1 (A)	21/3/95	Special lease 270 - NE depression	<i>Cx. annulirostris</i>	2nd, 4th	2	1.80
1 (A)	21/3/95	Special lease 270 - NE depression	<i>Cx. annulirostris</i>	2nd - 4th	50-100	0.64
1 (B)	22/3/95	Special lease 270 - East	<i>Cx. annulirostris</i>	3rd, 4th	2	1.35
			<i>Cx. sitiens</i>	pupae	1	
1 (B)	22/3/95	Special lease 270 - East (pool 50 x 75 m) algae, sedge grass	<i>Cx. annulirostris</i>	3rd, 4th	30	0.70
1 (B)	22/3/95	Special lease 270 - East, reed pool	<i>Cx. annulirostris</i>	3rd, 4th	5	1.62
1 (C)	21/3/95	Special lease 270 - SE end, grass edge of small pool	<i>Ae. vigilax</i>	2nd, 3rd	5	1.82
			<i>Cx. annulirostris</i>	2nd	1	
1 (C)	21/3/95	Small pool, grass - SE end	<i>Cx. annulirostris</i>	1st - 4th	10	0.14
1 (D)	22/3/95	Special lease 270 - West	<i>Cx. annulirostris</i>	2nd - 4th	5	0.80
			<i>An. hilli</i>	4th	1	
2	20/3/95	Wallaby Beach - E end behind dunes	<i>Ae. vigilax</i>	2nd	1	0.01
3	22/3/95	"Duck Pond" north margin, pigweed edges	<i>Cx. annulirostris</i>	2nd	2	2.30
4	20/3/95	Wallaby Beach, Oval sewage pond	<i>Cx. annulirostris</i>	2nd - 4th	4	0.32
5	20/3/95	South of Wallaby Beach sewage ponds. Grassy pool	<i>Cx. annulirostris</i>	4th	1	0.65
6	20/3/95	Reed swamp west of sewage pond	<i>Culex sp.</i>	siphon only	1	0.56
7	20/3/95	Gurrakpuy Beach - West of Yacht club	<i>Culex sp.</i>	1st, 2nd	1	0.50-0.70
11	21/3/95	Salt flat, S Dimbuka Rocks. Amongst reeds at edge	<i>Cx. annulirostris</i>	2nd, 4th	20	6.77
14 (A)	22/3/95	Crocodile Creek. Mangroves, western edge, Eleocharis reeds	<i>Ur. lateralis</i>	3rd, 4th	2	1.01
			<i>Cx. annulirostris</i>	2nd	30	
			<i>Cx. halifaxii</i>	4th	1	
14 (B)	22/3/95	Crocodile creek. Mangrove/paperbark margin	<i>Cx. annulirostris</i>	1st, 4th	10	2.17
15	23/3/95	Western mud flats, Mangrove/paperbark margin	<i>Cx. annulirostris</i>	pupae	1	18.14 - 28.0
			<i>Cx. sitiens</i>	2nd - 4th	10	
16 (A)	23/3/95	Nhulunbuy Town sewage ponds (primary ponds) NW corner	<i>Cx. annulirostris</i>	3rd, 4th	10	0.34
			<i>Cx. sitiens</i>	3rd, 4th	90	
16 (B)	23/3/95	Nhulunbuy Town sewage ponds (south cnr. primary pond)	<i>Cx. annulirostris</i>	3rd, pupae	3	0.21
			<i>Cx. sitiens</i>	2nd - 4th	20	
18 (A)	22/3/95	Mt. Saunders sewage ponds, small area on margin	<i>Cx. annulirostris</i>	4th	2	0.42
18 (B)	22/3/95	Narrow drain (non-sewage) at rear of sewage ponds outlet. Algal scum	<i>Cx. annulirostris</i>	1st, 2nd	25	0.85

(A) indicates more than one habitat sampled in general area.

*Distilled water = 0.00 - 0.01 mS/cm

Sea water = 40 - 50 mS/cm

APPENDIX 1

MOSQUITO LARVAL SURVEYS NHULUNBUY 17-18 NOVEMBER 1993

LARVAL SITE NO.	DATE	LOCATION	NUMBER OF LARVAE PER DIP	SPECIFIC CONDUCTIVITY (ms/cm)	SPECIES
1	17/11/1993	Buffalo Ck. Mid length - 1m wide dense mangrove cover. Channel- water 1m deep. Chironomid midges - larvae.	nil	71.4	
2	17/11/1993	Buffalo Ck. limit of water - dense mangrove cover, upper reaches.	nil	71.6	
3	17/11/1993	Rainbow Cliff Creek. 2km north of Buffalo Ck. upper reaches of lateral creek parallel to frontal dunes. open pooling.	three (3)	88.3	Ae. vigilax 3rd instars
4	17/11/1993	Rainbow Cliff Ck. Beneath dense mangroves in isolated permanent pools in main flow line.	thirty (30)	78	Ae. vigilax 3rd instars
5	17/11/1993	Wallaby Beach. Limit of tide in pool at start of pipe under old causeway.	five (5)	52.8	Ae. vigilax 2nd instars
6	18/11/1993	Wallaby Beach. Limit of tide in pool at start of pipe under old causeway.	five (5)		Ae. vigilax 3rd instars
7	18/11/1993	Wallaby Beach. Drimmie Causeway area between security ponds and old causeway directly south of sewage ponds. Area of pooling beneath Avicennia amongst pneumatophores. Reached by successive tides after initial hatch		52.8	Ae. vigilax 3rd / 4th instars
8	18/11/1993	Western mud flats. Creek drains to East Woody Ck. Salt water end of creek from Mt.Saunders Creek. Flow lines with gouge pools at limit of 3.4m tide.	hundred (100)	68.5	Ae. vigilax 4th instars
9	18/11/1993	Nhulunbuy Lagoon. End of access road at limit of water. Eleocharis reeds and dead mangroves.	nil	10.68	